Influence of goose grazing on plant availability of nutrients

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Influence of goose grazing on plant availability of nutrients

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ABSTRACT

Nutrient availability is a primary limiting factor of biotic functioning in Arctic environments. We hypothesized that geese, whose numbers have increased dramatically, impact on the plant availability of nutrients. The moss layer was thought to play a key role herein. To test for these hypotheses we measured plant availability of macro- and micronutrients over the winter and growing season and moss depth in a goose exclosure experiment. Our results show that important nutrients were significantly influenced by goose grazing. For some elements this could be partially explained by the grazing impact on the moss layer. During the winter season nutrient availability was remarkably high and was influenced by geese, urging the need for more ecological research during this period.

Keywords: *Nutrient availability, nitrogen, goose, Arctic, moss, PRS^{TM}-probes, winter processes*

ARTICLE

Nutrient availability is a primary limiting factor of biotic functioning in Arctic environments. Geese, whose numbers increased dramatically over the past 50 years due to human induced changes, were found to impact cycling and availability of nitrogen (paper 3, Ruess et al. 1989). Possible mechanisms of goose grazing impact are: (i) the impact on resource quality for decomposition by changes in vegetation composition (Bazely and Jefferies 1986, Gauthier et al. 2004, Kuijper et al. 2009) and the production of faeces, which are easily decomposable and high in readily available nutrients, (ii) the fragmentation of the dead plant material and the incorporation of litter into the soil due to trampling, accelerating decomposition and net nitrogen mineralization (Zacheis et al. 2002, Sorensen et al. 2009) and (iii) the reduction of the moss layer which is of crucial importance for ecosystem functioning (van der Wal et al. 2001, Gornall et al. 2009).

Whereas we do not want to neglect the importance of the first two mechanisms, the impact on the moss layer is likely to play a key role in the goose grazing effect on nitrogen availability for plants. The depth of the isolating moss layer indeed governs soil temperature, soil moisture and the number of freeze-thaw cycles, all of crucial importance for decomposition and mineralization processes (see also paper 1 and 3, Campbell et al. 2005, Gornall et al. 2007). A reduction in the moss layer might result in warmer and wetter soils containing more plant available nitrogen as found by Gornall et al. (2007). Moreover, ion exchange capacity of mosses is typically high and mosses are able to effectively take up nutrients through their entire surface because they lack a cuticle (Brown and Bates 1990). As a consequence mosses may swiftly take up soluble nitrogen preventing further access for vascular plants (paper 3, Kotanen 2002, Sjögersten et al. 2010).

Although the same mechanisms might hold for other nutrients, virtually nothing is known about the effect that geese might have on the plant availability. This study aims to fill this knowledge gap by addressing following questions: (1) Does goose grazing affect the availability of macro- and micronutrients for plants? (2) Does the moss layer play a key role in this process? This study aims to answer these questions by studying the plant availability of both macro- and micronutrients in the wet moss tundra-dominated brood-rearing area of the Kongsfjorden Barnacle goose population *Branta leucopsis* (Bechstein, 1803), Spitsbergen (78° 55' N, 11° 56' E). Nutrient availability was determined in three series of long–term goose exclosures and their control plots (figure 4.1.A). More detailed information about the field site and experimental setup can be found in paper 2.

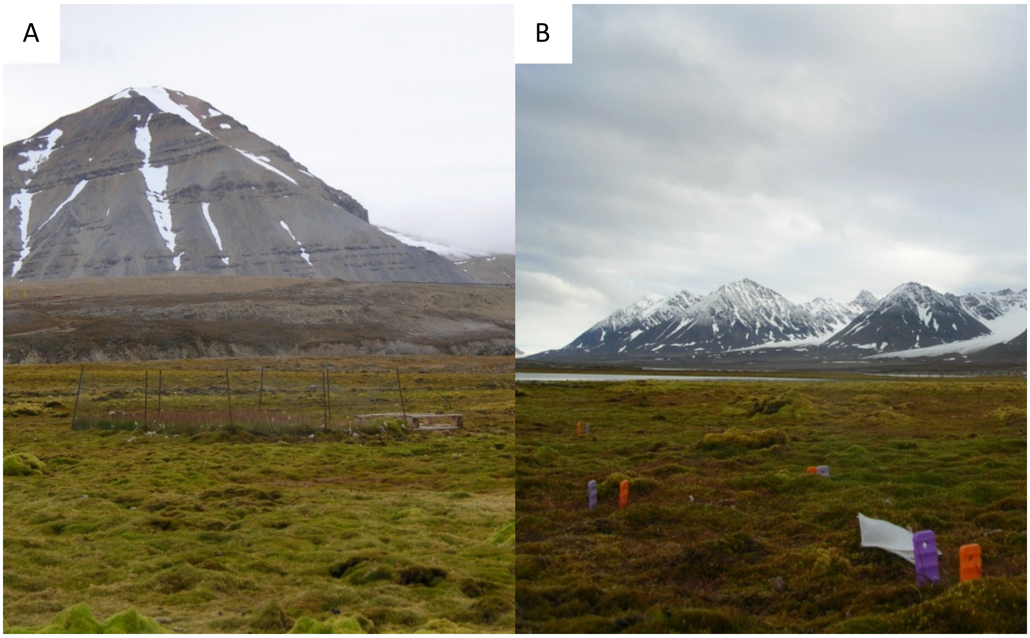


Figure 4.1. Experimental setup. a) Exclosure, mark the difference between the vegetation in and surrounding the exclosure. b) PRS™-probes in the field.

Nutrient supply rates for plants were assessed both during the winter (geese absent, 17/08/08-25/06/09) and the summer season (geese present, 25/06/08-17/08/08), using Plant Root Simulator probes (PRS™-probes, Western Ag Innovations Inc., Saskatoon, SK, Canada, figure 4.1.B). To account for soil heterogeneity within each replicate four pairs (i.e. cation- and anion-exchange) of PRS™-probes were spread throughout each experimental unit and combined for analysis. PRS™-probes were inserted vertically, downwards from the top of the rooting zone, at the start of the winter season when the soil started freezing. We removed buried PRS™-probes in spring just after snowmelt when the soil was still frozen and then re-inserted fresh PRS™-probes in the same soil slot until the end of the summer season. Such long-term burials allow accounting for temporal factors affecting nutrient supply, including ion diffusion from greater distances and the slow release of nutrients from mineralization and dissolution. After removal, the PRS™-probes were washed with deionized water, bulked according to treatment plot and transported on ice. In the lab probes were eluted for one hour using 0.5 M HCl. The eluate was analysed for levels of ammonium (NH_4^+) and nitrate (NO_3^-) using automated colorimetric flow injection analysis system (Technicon autoanalyzer, Bran and Lubbe, Inc., Buffalo, NY). Inductively-coupled argon plasma optical emissions spectrophotometry (ICP-OES, Optima 7300 DV, PerkinElmer) was used to measure levels of phosphorous (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B).

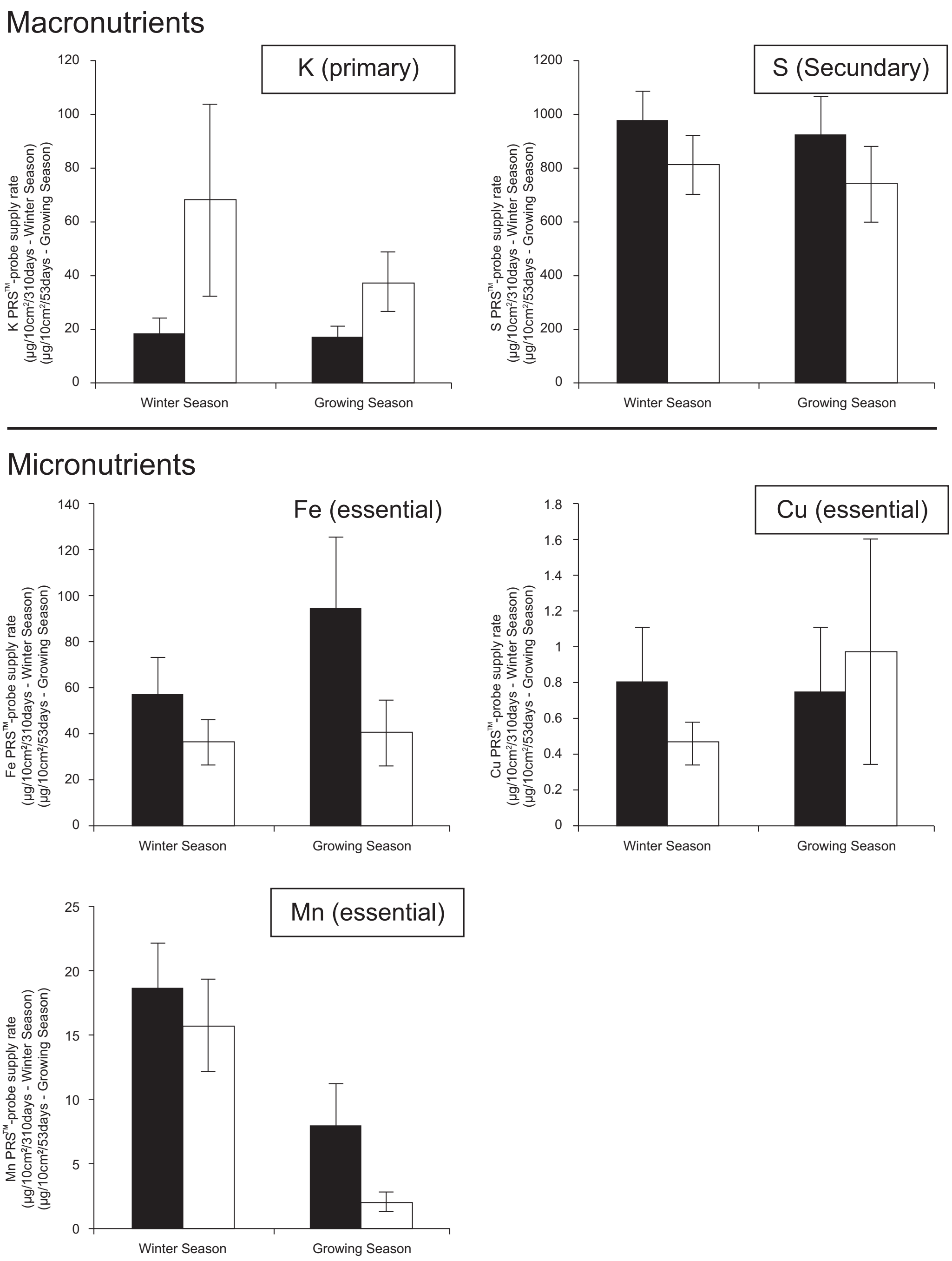
Difference in nutrient availability for plants between grazed and ungrazed plots was statistically tested with a three-way ANOVA accounting for repeated measures. Goose exclosure was set as fixed variable, series and replica nested in series as random variables.

To investigate the role of the moss layer, turfs of 9 cm^2 to a soil depth of 10 cm were cut in each plot. At the four sides of the turfs the distance between the top of the moss layer and the moss-soil interface (the point where moss shed old plant material) was measured with a ruler. A mean for each plot was made and used for further analysis. Results from different time periods were analysed separately using an ANCOVA with moss depth as continuous variable and treatment (grazed – ungrazed) as categorical fixed variable. Series and replica nested within series were fit into the model as random variables. Effects were considered significant at $p \leq 0.05$. All statistical analyses were performed using SAS version 9.2 (SAS Institute Inc. 2008) and data were transformed if necessary to meet the requirement of normality.

In accordance to other studies, grazing significantly reduced the depth of the isolating moss layer with 1.65 cm (exclosure: 4.19 ± 0.46 cm, grazed: 2.54 ± 0.30 cm, $n = 15$, $t = -5.90$, $p < 0.0001$). However, this did not result in the expected increase in nitrogen availability. Actually, in contrast with the study of Gornall et al. (2007), we did not find a correlation between moss depth and nitrogen availability (table 4.1). Also, plant availability of phosphorous, magnesium, zinc and boron was not affected by either goose exclosure or moss depth (table 4.1).

However, our results show a significant effect of goose grazing on potassium, which is as a primary macronutrient needed in large quantities by plants, sulphur, a secondary macronutrient, and iron, manganese and cupper, all essential micronutrients (table 4.1, figure 4.2). The change in nutrient availability might be the result of a change in plant composition (paper 1, Thiisbukta plots), the production of faeces and the reduction of the moss layer. Analogue with previous research on nitrogen (Ruess et al. 1989, Gornall et al. 2007) higher nutrient availability was observed in the grazed plots for all the nutrients except for cupper during the growing season (no difference) and potassium.

Nutrients		Season	PRS™-probe supply rate (µg/10cm²/53days – Growing Season) (µg/10cm²/310days – Winter Season)		Results statistical analysis: Grazing effect (ANOVA)						Contribution moss layer (ANCOVA)					
					Season * Geese			Geese			Geese excl. moss			Moss		
			Grazed	Exclosed	*df*	*F*	*p*	*df*	*F*	*p*	*df*	*F*	*p*	*df*	*F*	*p*
Primary macro-nutrients	Total N	Growing	49.3 ± 24.5	44.2 ± 22.6	1, 43.2	0.14	0.713	1, 44.2	0.91	0.345	1, 19.8	0.48	0.496	1, 23.3	0.05	0.830
		Winter	92.7 ± 36.8	102.4 ± 51.1							1, 17.4	1.24	0.280	1, 19.4	0.85	0.367
	NO_3-N	Growing	44.7 ± 24.7	39.6 ± 22.9	1, 43.2	0.00	0.978	1, 44.2	1.18	0.283	1, 19.9	0.44	0.513	1, 22.4	0.03	0.876
		Winter	89.9 ± 36.6	95.0 ± 51.2							1, 18.4	0.12	0.735	1, 20.8	0.00	0.963
	NH_4-N	Growing	4.76 ± 0.72	4.93 ± 0.72	1, 42.7	0.32	0.572	1, 43.7	0.57	0.454	1, 22.9	1.08	0.317	1, 20.1	1.59	0.222
		Winter	3.33 ± 0.39	8.67 ± 5.47							1, 22.6	4.20	0.052	1, 22.9	2.68	0.115
	P	Growing	2.06 ± 0.47	1.63 ± 0.35	1, 42.6	1.47	0.233	1, 43.6	0.04	0.849	1, 21.2	0.01	0.917	1, 16.6	1.12	0.305
		Winter	1.90 ± 0.44	2.24 ± 0.40							1, 18	0.80	0.383	1, 9.71	0.04	0.855
	K	Growing	16.69 ± 3.93	37.29 ± 11.17	1, 43	0.13	0.719	1, 44	6.47	**0.015**	1, 23.6	23.40	0.140	1, 23	0.11	0.740
		Winter	17.76 ± 5.96	67.80 ± 35.63							1, 26	0.00	0.954	1, 26	1.55	0.224
Secondary macro-nutrients	Ca	Growing	2045 ± 168	1766 ± 204	1, 42.4	1.71	0.198	1, 43.4	2.42	0.127	1, 19.2	0.83	0.375	1, 17.7	0.01	0.920
		Winter	2055 ± 116	2025 ± 156							1, 14.4	3.44	0.084	1, 17.1	6.81	**0.018**
	Mg	Growing	311.8 ± 21.5	292.3 ± 29.3	1, 42.6	1.14	0.292	1, 43.6	0.07	0.792	1, 20.7	1.28	0.271	1, 15.4	0.94	0.348
		Winter	327.4 ± 18.3	340.3 ± 20.6							1, 21.8	0.17	0.680	1, 25.5	0.04	0.838
	S	Growing	922 ± 142	740 ± 142	1, 42.4	0.02	0.892	1, 43.4	6.65	**0.013**	1, 9.54	0.41	0.537	1, 14.3	4.66	**0.048**
		Winter	977 ± 106	812 ± 110							1, 12.5	1.86	0.197	1, 14.4	11.71	**0.004**
Micro-nutrients	Fe	Growing	94.75 ± 30.88	40.14 ± 14.34	1, 42.8	0.40	0.534	1, 43.8	6.58	**0.014**	1, 21.4	0.00	0.980	1, 27.7	3.54	0.070
		Winter	57.24 ± 15.87	36.13 ± 9.84							1, 19.6	0.39	0.538	1, 24.4	3.90	0.060
	Mn	Growing	8.01 ± 3.26	2.09 ± 0.79	1, 42.6	8.46	**0.006**	1, 42.6	7.38	**0.009**	1, 22.1	4.01	0.058	1, 25.4	0.00	0.944
		Winter	18.67 ± 3.54	15.78 ± 3.58							1, 12.5	1.40	0.258	1, 24.4	1.58	0.220
	Cu	Growing	0.75 ± 0.36	0.98 ± 0.63	1, 43.2	2.66	0.11	1, 44.2	4.55	0.039	1, 23.5	0.34	0.563	1, 25.7	1.42	0.245
		Winter	0.81 ± 0.30	0.46 ± 0.12							1, 16.4	1.12	0.305	1, 12.2	0.88	0.366
	Zn	Growing	3.01 ± 1.29	3.31 ± 1.69	1,42.2	0.02	0.899	1, 43.3	1.34	0.253	1, 20.3	2.72	0.114	1, 24.9	2.06	0.164
		Winter	2.40 ± 0.69	2.41 ± 0.46							1, 17.1	0.02	0.894	1, 24.6	0.77	0.387
	B	Growing	1.88 ± 0.16	1.76 ± 0.12	1, 41.9	0.00	0.981	1, 42.9	0.96	0.333	1, 23.2	1.45	0.240	1, 27.9	0.40	0.534
		Winter	1.97 ± 0.13	1.86 ± 0.11							1, 22.6	0.12	0.732	1, 20.1	0.02	0.885



↑ Figure 4.2. Plant availability of some macro- and micronutrients expressed as mean PRS™-probe supply rate, error bars represent standard errors. Plant availability of the shown elements differed significantly ($p < 0.05$) between grazed plots (black bars) and exclosures (white bars).

← Table 4.1. Plant availability of macro- and micronutrients, measured as PRS™-probe supply rate, in grazed plots and exclosures. Mean values ± SE and the results of the statistical tests are given. Significant ($p \leq 0.05$) results are indicated in bold.

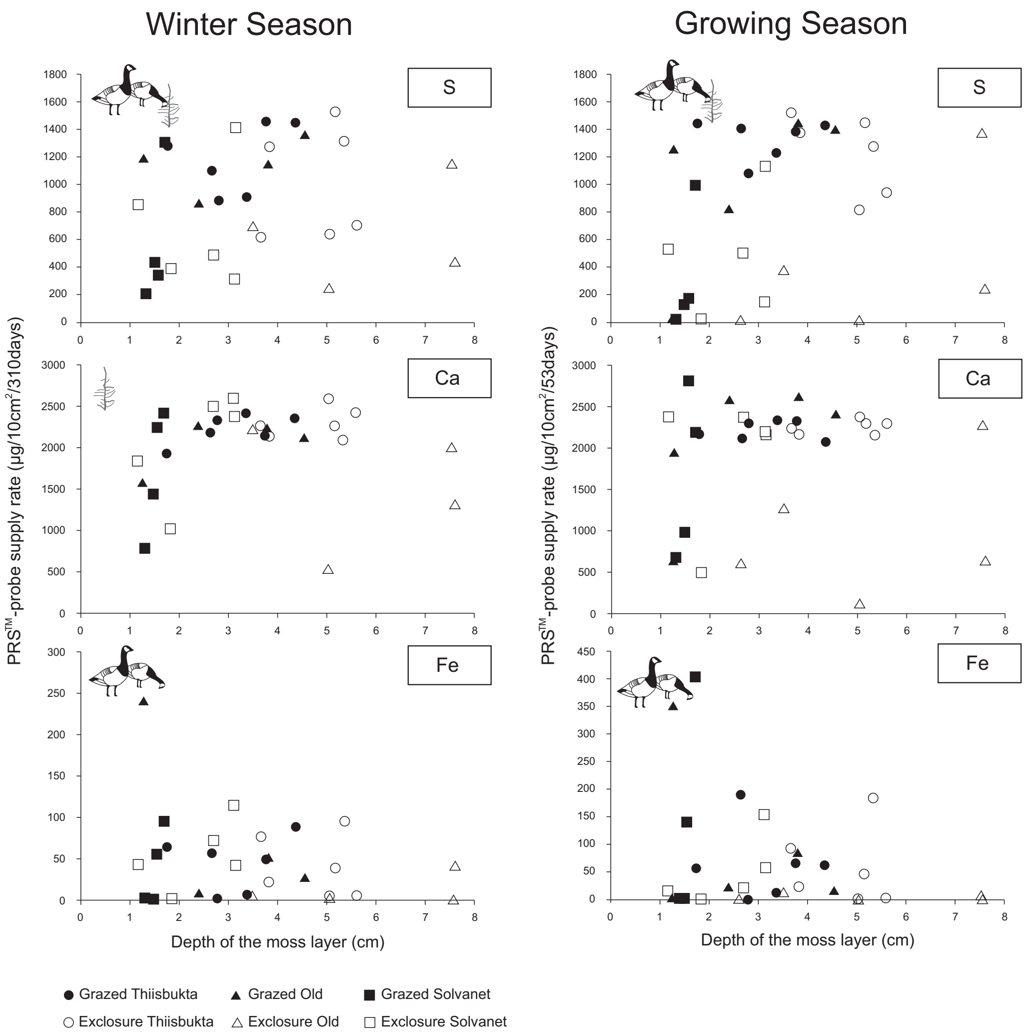


Figure 4.3. Plant availability of some macro- and micronutrients in function of the depth of the moss layer in grazed plots and exclosures. Significant differences ($p \leq 0.05$) between grazed and ungrazed plots in plant availability are indicated by , a significant correlation between moss depth and plant availability by .

Separating the effect of the reduced moss layer and 'other grazing mechanisms' revealed that - except for manganese during the growing season - the nutrient availability is not significantly influenced by 'other grazing mechanisms' only (table 4.1). The grazing impact on nutrient availability is thus at least partly mediated by the moss layer. For sulphur and calcium (only winter season) we even found a significant positive correlation between the plant availability and the depth of the moss layer, for iron this correlation was negative and only marginally significant (table 4.1, figure 4.3). This suggests that other mechanisms than the insulation capacity of the moss layer and the absorption of nutrients by mosses (Gauthier et al. 1995, Kotanen 2002) might underlay the moss effect on the availability of sulphur and calcium. Indeed, based on these mechanisms we expected an increased nutrient availability due to the moss layer reduction by grazing as observed for iron in this study and nitrogen in the study of Gornall et al. (2007).

Until now most ecological research concerning nutrient availability is limited to nitrogen and sometimes also phosphorous. However, as the overall effect of goose grazing on plant availability of nutrients and the underlying mechanisms seems to differ considerably between elements, we urge to broaden the scope of this research to other essential plant nutrients. In addition we want to emphasize the need to continue ecological studies during winter when geese are absent as nutrient availability outside the growing season is relatively high and for some elements influenced by grazing.

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